NEURAL NETWORK APPLICATIONS LABORATORY

IMPLEMENTED AT THE SAN ANTONIO AIR LOGISTICS CENTER

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INTRODUCTION

A neural network applications laboratory was installed and implemented at the San Antonio Air Logistics Center, Kelly Air Force Base, Texas. Implementation was a part of a technology insertion thrust to apply technology for continuous product / process improvement in aircraft and engine maintenance operations. Applications laboratory capabilities were established by integration of knowledge, computer equipment, software tools, example methodologies, selected specific application procedures, reference materials and personnel training. The system is hosted on two *SUN Microsystems* workstations with support peripheral and an Ethernet link to the *MicroVAX* system that hosts the Computed X-ray Tomography (CAT) system. Commercial and public domain software tools were provided to perform routine data preparation and image processing tasks. Public domain neural network software tools were provided to enable user application. Three test examples were developed using test / image data from the computed X-ray tomography (CAT) system in the "Nondestructive Testing Section, Kelly Science and Engineering Branch at Kelly Air Force Base". The system was validated with computed X-ray tomography data, but is applicable to a variety of nondestructive evaluation data that is collected and stored in electronic format. The system was fully functional on 15 June 1993.

As often happens, other applications of new tools are found after the system becomes functional. Application of the system in reverse engineering applications are discussed in this paper.

BACKGROUND

The United States Air Force has an initiative for technology development and implementation in design, production, acceptance and maintenance overhaul operations. As a part of this initiative, an x-ray computed tomography capability was acquired for use in the support of aircraft structures and gas turbine engine overhaul applications at Kelly Air Force Base, Texas. Implementation of the technology into the Kelly work flow has required acquisition of the knowledge and skills required to use the system, and re-analysis of work functions to assess added capability, measurement precision, reliability and productivity. At the same time, the nature of the data / information output from the system has offered opportunity to analyze data, extract information and make decisions in a way that was not previously possible. For example, image analysis, information extraction and decision processing which had been previously performed by manual reading of film x-radiographs was now available in electronic form and could thus be processed using automated tools. A task was initiated to interface the output from the computed tomography (CT) system to an “Automated Nondestructive Evaluation System” (ANDES) being developed under contract to the Air Force, Phillips Laboratory (REF 1) to provide a user driven information extraction and decision processing capability for use on nondestructive evaluation (NDE) data. Pre-screening and data interface to a defined format are required as inputs to the ANDES system. Since data from the CT system are provided in a reconstructed image form, an image processing / information extraction capability was required to provide the interface link to the ANDES system. Due to the widely varying test object types that are processed through the Physical Sciences Laboratory at Kelly AFB, user selected and configured data interface, data processing and image processing tools were provided to make the system adaptable to a wide range of tasks and operating requirements. Custom data interface and data transfer tools were provided as part of the ANDES system. Image processing tools were provided in the form of a linked "public domain" software package graphical interface called "Khoros" which was developed at the University of New Mexico (REF 2). The neural network package chosen was "Aspirin / Migraine" which was developed by the Mitre Corporation (REF 3). A general purpose decision processing module was provided as part of the ANDES system. The combined ANDES system offers user selected options in data extraction, data processing, image processing and information extraction. Information is then provided to the decision processing module in the defined ANDES format. Decision processing is performed in accordance with user defined parameters and acceptance criteria through a scripting language interface. The decision processing parameters are configuration controlled by the ANDES system and can be applied to multiple test applications. The data and image processing is user defined through a graphical programming interface and multiple applications of the same process are provided by custom C++ programming.

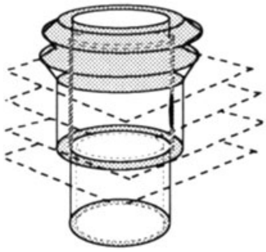


Figure 1. Cross section of a scavenger tube braze joint.

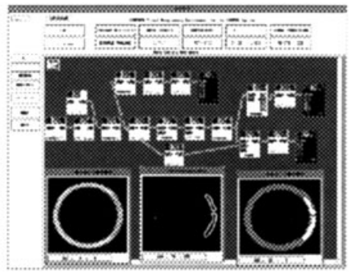


Figure 2. The "Khoros - Cantata" workspace.

ANDES SYSTEM PROCESSING

An example of full ANDES system processing is described in processing of induction brazed tube assemblies the performed during overhaul / refurbishment of gas turbine engines. The scavenger tube assembly is induction brazed to join a pressure connector fitting to a stainless steel tube (see Figure 1). Functional requirements for the joint are strength and a leak free attachment. Acceptance criteria for strength is that 60% of the total joint area must be wet (brazed). Traditional acceptance is by through-section x-radiographs taken at 0° and 90° (view angle, radial). Manual read-outs of the x-radiographs are performed by skilled operators. Voids in the braze alloy appear as light areas of random shape. Elongated voids or aligned groups of voids are grouped to make a decision on leak path potential. The total unbrazed area is determined by adding all unbrazed areas together assess acceptance per the 60% joint strength criteria. Translation of the x-radiographic acceptance criteria to CT criteria is performed by data extraction of void / unbrazed area from individual CT slice images and passing the slice information to the ANDES decision processing module. In processing individual slice images it is necessary to:

1. Locate the braze joint image within the reconstructed CT slice image field; (performed by a neural network or morphology operator in a moving window mode)
2. Normalize the image densities of all image slices; (image density adjustment to a predetermined area on each slice)
3. Locate the braze joint interface within the joint image;(neural network or morphology operator in a moving window)
4. Quantify the size and location of braze anomalies within the braze joint; (masking and image metrics)
5. Format the extracted data in the ANDES decision processing module interface format; (documentation of each anomaly within each slice image) and
6. Transfer extracted image data to the ANDES decision processing module.

A screen image of the slice image processing interface is shown in Figure 2. The unbrazed areas and masks are shown on the right side of the image. Information on the size and location of the unbrazed areas are calculated directly from the image area and passed on the ANDES module.

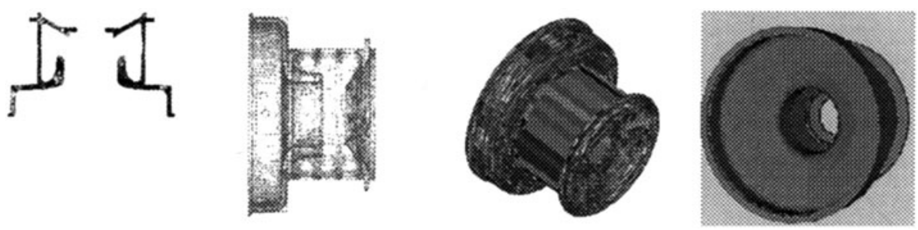
The ANDES decision processing module accepts the data and provides accept / reject recommendations and reporting based on anomaly type, size, location, orientation and nearest neighbor. In this case the anomaly type is well defined and acceptance can be made on the basis of individual void size and cumulative void area. An added nearest neighbor analysis for leak path is completed by assessing void overlap in contiguous slices. A report is provided in accordance with the information extracted in image processing

REVERSE ENGINEERING FROM CT IMAGE DATA

Alternate use of the ANDES image processing tools have been made by capturing and enhancing the CT slice images using the available image processing tools (primarily edge enhancement) and porting the image data in the required image format to an "AUTOCAD - Version 12" computer aided design (CAD) package. A wire frame model of the slice can be generated from the image data. Slices are then stacked and "linked" to produce an integrated wire frame model and may then be converted to a solid model. Dimensional tolerances can be added by the engineer / user to provide a usable engineering CAD file. This file can then be transferred to a prototype modeling system (such as a "Stereo lithography" system) and a replica component is produced in the prototype system. The reverse engineering process has potential for use in a number of areas and has particular potential utility in producing patterns for replication and mass production of castings.

Figure 3a. shows the cross section of a turbine inlet housing imaged as a single CT slice. Figures 3b., 3c. and 3d. show progressive steps in processing from a linked slice, wire frame model to a final solid model of this component.

Figure 4 shows a linked slice model of an aircraft helmet that was used to measure conformal shape and dimensional tolerances. This data provided the information necessary for redesign of the face piece for greater comfort to the wearer.



a. Cross section b. Wire frame c. Brick Model d. Solid Model

Figure 3. Progressive steps in building the solid model.

Figure 4. Helmet Model   Figure 5. Cast Ring Model   Figure 6. Bones

Figure 5 is the solid model of a cast ring component that was used in replication of the casting. It is important to note that this technology also be used to improve the casting patterns and sprue designs for higher product yield.

Figure 6 is the reconstructed model of bones for use in archeology in species identification, skeletal reconstruction and species model reconstruction.

SUMMARY

Linking the three dimensional imaging capabilities of computed X-ray tomography with image processing and solid modeling tools offers potential for reverse engineering; the linkage of modeling, prototype and production process improvement; and the inspection of complex objects. The techniques and objects used for demonstration provide a basis for the expansion of capabilities and improvement in precision

ACKNOWLEDGMENT

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REFERENCES

1. Rummel, Ward D., Davis, Mark and Garcia, Rodolfo, "Computed Tomography in Turbine Engine Overhaul", *Review of Progress in Quantitative Nondestructive Evaluation*, Volume 12, pp351-355.
2. "Khoros" is a trademark of the University of New Mexico, Department of EECE, Room 110, University of New Mexico, Albuquerque, NM 87131.
3. "Aspirin / Migraine", MITRE Corporation, MITRE Signal Processing Lab, 7525 Colshire Dr., McLean, VA 22102.